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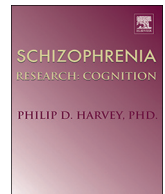
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## Research paper

## Non-literal understanding and psychosis: Metaphor comprehension in individuals with a diagnosis of schizophrenia

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## ABSTRACT

Previous studies suggest that understanding of non-literal expressions, and in particular metaphors, can be impaired in people with schizophrenia; although it is not clear why. We explored metaphor comprehension capacity using a novel picture selection paradigm; we compared task performance between people with schizophrenia and healthy comparator subjects and we further examined the relationships between the ability to interpret figurative expressions non-literally and performance on a number of other cognitive tasks. Eye-tracking was used to examine task strategy. We showed that even when IQ, years of education, and capacities for theory of mind and associative learning are factored in as covariates, patients are significantly more likely to interpret metaphorical expressions literally, despite eye-tracking findings suggesting that patients are following the same interpretation strategy as healthy controls. Inhibitory control deficits are likely to be one of multiple factors contributing to the poorer performance of our schizophrenia group on the metaphor trials of the picture selection task.

## 1. Introduction

Figurative language, in which the speaker intends to communicate something other than what is linguistically encoded, is pervasive in human communication (Bowdle and Gentner, 2005). Metaphorical expressions such as “Hope is the knot at the end of a rope”, in which the attributes of one item are ascribed to another, have been reported to be used six times in every minute of discourse (Gibbs, 1994).

Like everyone, patients with a diagnosis of schizophrenia have been exposed to non-literal language from the moment they enter the linguistic realm, yet they are considered to be impaired in their ability to accurately interpret non-literal expressions during acute episodes of psychosis and when in remission (Drury et al., 1998; Mo et al., 2008), and to have difficulty with the contextually dependent aspects of language (inferring meaning in context) more generally (Bazin et al., 2005; Colle et al., 2013; Haas et al., 2015; Langdon et al., 2002; Linscott, 2005). Indeed, the propensity to “take things too literally” or for “concrete thinking” has long been considered to be a characteristic of schizophrenia (Harrow et al., 1974). This impairment in interpretation of figurative language is associated with reduced sensitivity to social

cues (Corrigan and Green, 1993), is negatively correlated with insight (Nakano et al., 2004) and is shown in those with diagnoses of schizophrenia spectrum-disorders (Mossaheb et al., 2014). Previous studies of metaphor comprehension have relied on participants giving verbal explanations to stories which incorporate figurative language (Drury et al., 1998; Mo et al., 2008) or to proverbs (Haas et al., 2015). However, it is not clear whether the apparent deficits shown in these studies are consequent on metaphor processing per se or on the metalinguistic processing required for the test response. Moreover, it is not fully understood whether the metaphor processing deficit is a specific impairment or whether it is part of (or indeed driven by) a broader array of cognitive impairment, including for instance deficits in Theory of Mind (ToM) (the ability to attribute mental states to oneself and to others), IQ, broader aspects of language comprehension or working memory capacity.

On encountering a metaphor, the hearer must arrive at a figurative interpretation based on numerous contextually determined variables. There is now, largely, a consensus to reject sequential processing models of metaphor, in which a default literal interpretation must first be arrived at and rejected, as contextually inappropriate, before a more

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appropriate alternative meaning can be derived. Instead, parallel processing models are favoured (Gentner et al., 2001; Glucksberg et al., 2001; Rubio-Fernández et al., 2015). It remains a matter of debate how nominal metaphors of the form X is Y (e.g., the fridge is a monster) are processed, specifically whether they are processed as categorization statements (Carston, 2002; Glucksberg et al., 2001; Wilson and Carston, 2007) or as implicit comparison statements (Clement and Gentner, 1991; Forbus et al., 1994; Gentner et al., 1993; Wolff and Gentner, 2011). However, most current accounts endorse the view that, during the processing of novel nominal metaphors, features associated with the literal meaning of the metaphor vehicle, in this example the “monster”, which are not relevant to the metaphorical interpretation, are not attended to (lose activation), while those features that are relevant to the interpretation are attended to (remain activated). Some authors have interpreted their findings as providing evidence of active inhibition of metaphor irrelevant features during the processing of novel metaphors (Gemsbacher et al., 1995; Gernsbacher et al., 2001; McGlone and Manfredi, 2001; Papagno et al., 2003; Pierce et al., 2010; Rubio-Fernández, 2007). It is notable therefore that impaired inhibitory control has been shown in Alzheimer's disease (Amanzio et al., 2008; Papagno et al., 2003), Asperger syndrome (Gold et al., 2010), Parkinson's disease (Monetta and Pell, 2007) and schizophrenia (Badcock et al., 2002; Mossaheb et al., 2014; Thoma et al., 2009) – all conditions associated with metaphor comprehension deficits (Amanzio et al., 2008; Hermann et al., 2013; Mo et al., 2008; Monetta and Pell, 2007; Roncero and de Almeida, 2014) – and that individuals with Alzheimer's disease, on a sentence-picture matching task, appeared to recognise the correct interpretation of figurative statements but failed to suppress the selection of a salient but contextually inappropriate literal alternative (Papagno et al., 2003). Previous findings have also suggested that impaired inhibitory control deficits are associated with poorer metaphor comprehension capacities in schizophrenia (Badcock et al., 2002; Mossaheb et al., 2014; Thoma et al., 2009). However, these studies did not explicitly build inhibition into the metaphor task. Rather, this conclusion was drawn on the basis of an association between performance on a metaphor task and performance on an inhibitory control task. The disorders mentioned above are characterized by a number of cognitive deficits which might contribute to difficulties in metaphor comprehension. This association between impaired inhibitory control and metaphor comprehension deficits has allowed authors to assume a causal mechanism but this assumption has not been effectively tested, which means we can't rule out the possibility that this might be an epiphenomenon.

Theory of mind (ToM) has also been shown to be impaired in schizophrenia (Brüne, 2005; Frith, 1992; Harrington et al., 2005), which is relevant because it has been argued that a fully developed ToM is required in order to arrive at non-literal interpretations (Happé, 1993). Relevance theorists Sperber and Wilson, argue that “communication exploits the well-known ability of humans to attribute intentions to each other” (Sperber and Wilson, 1995) and that, therefore, individuals who have impaired ToM, and who, as a result, cannot attribute beliefs and intentions to other people proficiently, will have difficulty comprehending utterances in which the speaker intends to convey something over and above that which their utterance encodes, especially metaphorically intended utterances. This is taken to provide an explanation of why children under the age of 4 and individuals on the Autistic Spectrum appear to have difficulty comprehending metaphors. Both populations fail false belief tasks ((Happé, 1993; Norbury, 2005), e.g. the Sally-Anne task (Wimmer and Perner, 1983)), which are taken to be indicative of whether or not an individual has first order (first-order false-belief tasks require the attribution of false beliefs to others within the context of real events; whereas, second-order false-belief tasks require the participant to reason about other people's thoughts/beliefs) ToM (Baron-Cohen et al., 1985; Bartsch and Wellman, 1995; Gopnik and Meltzoff, 1997; Gopnik and Wellman, 1994; Perner, 1991; Wellman and Gelman, 1998; Wimmer and Perner, 1983).

Pouscoulous and Tomasello's (Pouscoulous and Tomasello, 2011) and Deamer's (Deamer, 2013) findings, however suggest otherwise; they show that children as young as 3-years-old, who would typically fail a false-belief task, are capable of interpreting basic metaphorical language. The role that mental state (or intention) attribution plays in metaphor comprehension is, therefore, not clear-cut. In schizophrenia studies, subjects are shown to underperform on simple social inference tasks compared with healthy controls and with non-psychotic psychiatric control groups, but the relationship between social inference (including ToM) and non-literal language comprehension is inconsistent (Mo et al., 2008). It is possible that contradictory findings are reflective of insufficient statistical power or the use of metaphorical materials which place different demands on ToM capacity. Metaphors that pertain to emotions and feelings (“The man exploded”, said of a very angry man) might require more mental state attribution and understanding of affective associations (i.e., anger-explosion) than purely perceptual metaphors (“The man was a tomato”, said of a man with a red complexion). It is possible that impaired ToM in schizophrenia might present a barrier to accurately comprehend emotionally expressive metaphors but not purely perceptual metaphors.

In this pilot study, we set out to examine metaphor processing using an action, rather than verbal, response to ameliorate any potentially confounding metalinguistic competency deficits (Deamer, 2013), in order to establish the metaphor comprehension capacities of people with schizophrenia. To select the correct figurative picture from literal and control foils in this task, the participants must resist the temptation to interpret the expression literally while processing spoken stories. Instead, they must rely on the context in order to make a pragmatic inference about the meaning of the metaphorical statement. We tested participants' comprehension of novel metaphors. We avoided conventional metaphors to make sure we were not testing prior acquisition of their lexicalized meaning, but, rather, the ability to arrive at an accurate, contextually relevant interpretation. We also tracked participants' eye movements and fixations while they made their picture selection in order to explore the underlying processes of metaphor interpretation, as these measures allowed us to assess the extent to which patients implicitly processed the different picture types (e.g., ability to inhibit looking at the literal picture). There is a large literature validating the use of fixation time measure to access higher order cognitive processing (see Rayner and Morris, 1990 for a thorough review). This literature strongly suggests that there is a close relationship between what someone is looking at, and what they are processing. Moreover, Poyner and Morris (2003) demonstrate that the eye-fixation duration measures are sensitive to the process of generating inferences.

By tracking the participants' eye fixations as they interpret target sentences metaphorically, hyperbolically and literally, we will be able to see in real-time, the regions of the picture that they are fixating on at any given point during the process of making their selection. Reading-times provide us with a measure of a quantitative difference between the processing of the two tropes, but the use of different kinds of eye-tracking measures should allow us to make inferences about the existence of qualitative differences between the processing of metaphors and literal items.

Lastly, we investigated the role of other putative confounding variables that may impact metaphor comprehension including illness and cognitive factors, current and pre-morbid IQ, years of education, ToM and associative learning capacities.

In summary, the methodology outlined below was put in place as a pilot study to address the following question; do individuals with a diagnosis of schizophrenia have more difficulty processing metaphorical language than their healthy counterparts, and relative to comparable literal language? We hypothesised that, even when any potentially confounding metalinguistic competency deficits are ameliorated (as in our study design), individuals with a diagnosis of schizophrenia will show reduced performance (slower response times, more incorrect picture selections, and increased fixation times on the

literal picture on metaphor trials) on the metaphor comprehension task relative to healthy controls.

## 2. Method

### 2.1. Participants

As part of the Psychosis and Language Study (Cokal et al., 2018), 19 (6 males) monolingual English speaking participants with a diagnosis of schizophrenia were recruited from Northumberland, Tyne and Wear NHS Foundation Trust. Fifteen (8 males) monolingual English speaking healthy controls were also recruited by local advertisement. Informed consent was obtained from all participants. Patients and comparators were matched for age, and reported years of full time education. 16 of the patients were taking at least one antipsychotic (7 clozapine), 1 was taking sodium valproate, 3 antidepressants, 3 a benzodiazepine, 1 pregabalin, 1 propranolol and 1 codeine. Patients had a mean lifetime illness duration of 209 (STD = 108.5) months. A National Adult Reading Test (NART) (Nelson, 1982) was used as a measure of pre-morbid IQ, a Wechsler Abbreviated Test of Intelligence (from which the full scale IQ was calculated) (Wechsler, 2008) and a Positive and Negative Syndrome Scale (Kay et al., 1987) was completed with each participant, and we generated a full scale IQ (FSIQ) using the Wechsler Adult Intelligence Scale (Table 1).

### 2.2. Picture selection task (PST)

After being presented with clear instructions (from a written script to ensure consistency), the participants heard a series of pre-recorded stories, presented in random order, one at a time. There were fifteen metaphor stories (Rubio-Fernandez, 2007) and seven literal stories (Deamer, 2013) (see Appendix A). For the metaphorical stimuli, a series of common nouns were used as metaphor vehicles, with a metaphorically biased context for each of the nouns. Each context ended in a nominal metaphor of the form “X is a Y”, with X always being the metaphor topic, and Y the metaphor vehicle. As the metaphors were novel, the preceding context comprised one or two sentences to ensure that the nominal metaphor would be understandable (e.g. “After six months without going to the barber, John is a lion.”). The literal stories (e.g. “Sam and Mark had the weekend off, and went to a national park for the weekend. The national park was a forest.”) were matched for length with the metaphor stories. Duration of metaphor story recordings ranged from 4.68 to 9.64 s (mean: 7.34 s); literal story duration ranged from 6.48 to 10.84 s (mean: 8.74 s). Stories were presented once, and it was not possible to hear them a second time.

After each story, the participants were asked to mouse click on which of three similar pictures (presented to them in a triangular

format on the screen; see Fig. 1) “went together with the story”. In the case of the metaphor items there was: a metaphor picture (the appropriate response, depicting the metaphoric interpretation, e.g. a man with very long and messy hair), a control picture (which was related but did not contain any elements corresponding to either the literal or figurative meaning of the metaphorical expression), as well as a literal picture (including a literal interpretation of the target word in the background, e.g., a lion suit). The literal option was included to enable examination of whether participants were able to inhibit a literal interpretation of the metaphor vehicle, and was also designed to not represent a possible literal interpretation of the utterance as a whole (for example, if it had included an anthropomorphized lion) as asking the participant to select from two plausible interpretations – one metaphorical, the other literal – would examine metalinguistic rather than metaphor comprehension skills. The position of the three pictures was counterbalanced (between bottom right, bottom left and top middle) across trials. The trials were presented in a fixed order. All pictures were commissioned for this study. The task worked exactly the same for the literal items. However, the three pictures to select from were as follows: a correct picture (the appropriate response, depicting the intended literal interpretation), two control pictures (both contextually plausible in different ways but including no element corresponding to the intended literal meaning of the final sentence of the story).

In addition to the experimental items, there were two practice items which followed the same format as the experimental items without the use of a figurative expression; e.g., “This weekend, Sally is at the park. She is having lots of fun riding on her bike in the park. Can you find the picture of Sally riding her bike in the park?” see Appendix A for full list of practice and experimental items. Feedback was given to the participants during the practice trials, but not during the experimental trials.

### 2.3. Eye-tracking system

Eye movements were recorded using an Eyelink 1000 eye tracking system (SR Research Ltd., Ottawa, Ontario, Canada). Participants were seated at a distance of 117 cm from a 24-inch colour monitor at 1920 × 1080 pixel resolution. They positioned their chin and forehead on a chin rest to minimise head movement and ensure standardised distance from the monitor. The Eyelink system sampled participants' eye position at 1000 Hz from the onset of the pictures appearing on the screen to the point at which they made their picture selection (mouse click). With the chin rest, the system had an average spatial accuracy of 0.25°–0.5° and average resolution (variability) of 0.01°. These values were sufficient for the size of pictures we used. A 35 mm lens was focussed and orientated in the horizontal plane for monocular viewing. The eye that was most readily tracked was selected for data collection. A nine-point calibration and validation were performed before running the PST.

### 2.4. Theory of mind

The Revised Eyes Test (Baron-Cohen et al., 2001) was performed after the PST as an assessment of first-order ToM. Participants were presented with a booklet containing 36 photographs of the eye-region of different actors and actresses. Each photograph was accompanied by a choice of four words. Participants were instructed to choose “which word best describes what the person in the picture is thinking or feeling”. Selections were verbalised to an examiner who recorded responses. Participants scored one mark for each correctly identified word, yielding a maximum score of 36. Participants were advised to request the definition of words they were unsure of, which were read to them from the glossary if required.

### 2.5. Eye-tracking data pre-processing

The Eyelink system removed blinks and other eye-movement

**Table 1**  
Group comparison of demographic and cognitive characteristics.

	HC (n = 15) Mean (SD)	SCZ (n = 19) Mean (SD)	Group difference T (df) p
Age	45.1 (13.0)	42.5 (10.3)	0.649 (32) 0.521
Years education	16.3 (3.6)	13.6 (4.1)	1.998 (32) 0.054
Full-scale IQ (FSIQ-4)	106.9 (8.5)	89.0 (16.9)	3.74 (32) 0.001**
premorbid IQ (NART)	109.1 (8.7)	95.3 (14.5)	3.25 (32) 0.003**
PANSS	40.1(5.8)	97.2(18.3)	11.6 (32) < 0.0005**
TOM	28.0 (3.9)	22.5 (5.8)	3.1 (30) 0.004**

Comparison of demographic characteristics between healthy controls (HC) and participants with schizophrenia (SCZ) including age, years of full time education, IQ as measured using the full scale IQ-4 on the Wechsler Adult Intelligence Scale (WAIS), the National Adult Reading Test (NART) score which is used as an estimate of pre-morbid intelligence and Theory of Mind (TOM) measured using the Revised Eyes Test. Data shown is mean and, in parenthesis, standard deviation and the comparison column shows the results of independent t-test.

< .05



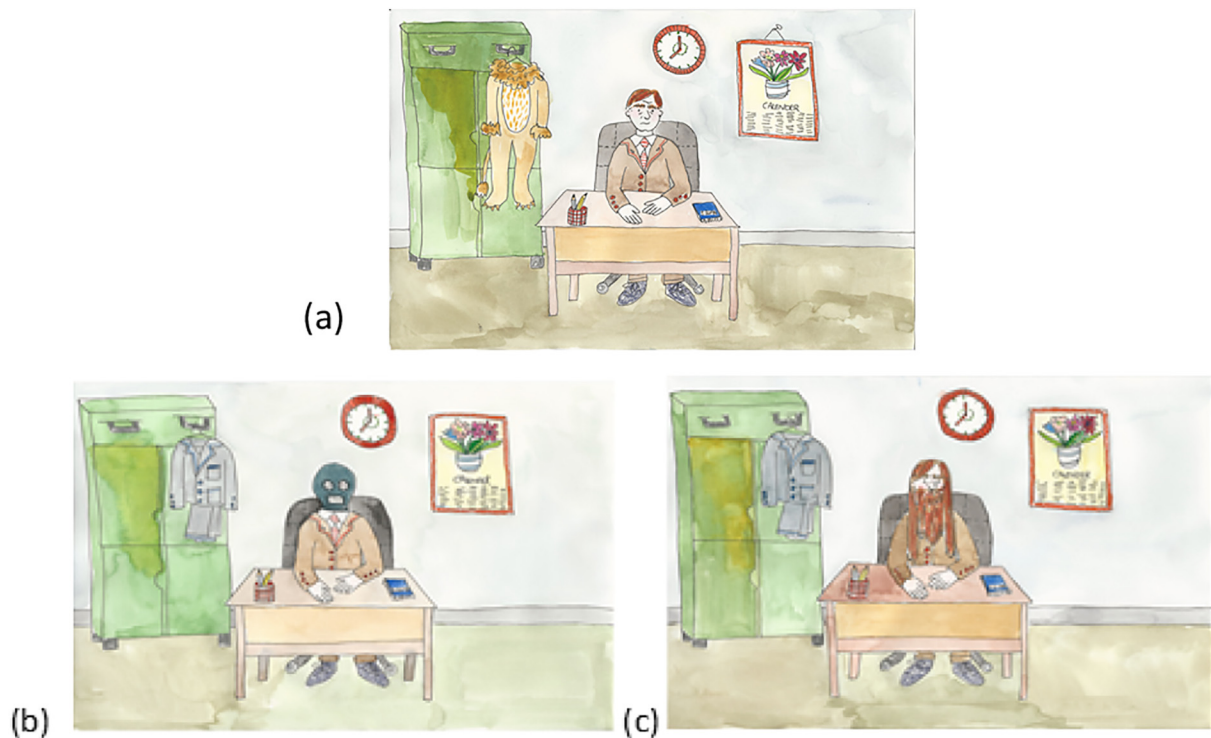


Fig. 1. Picture choices for the metaphor item “John was a lion”: Picture (a) is the literal picture, (b) the control and (c) the metaphor.

artefacts, and provided the x- and y-coordinates and duration of each fixation. To analyze the eye-tracking data, we defined areas of interests (AOIs) for two separate analyses. In the first analysis, the metaphor, literal and control pictures (on each trial) served as AOIs (as frequency and length of fixations on the different pictures will provide insight into the participants' decision making process prior to their picture selection). In the second analysis, the literal pictures of metaphor trials were divided into sixths; the sixth which contained the literal depiction of the metaphor vehicle (i.e., the literal target) was defined as an AOI (because more fixations or extended looking time in this area on metaphor trials would suggest a tendency to interpret metaphor vehicles literally, even if the participant is ultimately able to override this tendency to make the correct non-literal selection). The literal target for two pictures did not fall within one-sixth of the literal picture and so these pictures were excluded from the literal-target analysis.

For each participant and each AOI, we computed three measures from the eye-tracking data. First, we computed the mean looking time by summing the duration of all fixation within that AOI for each trial and then dividing by the number of trials. Second, we computed the mean proportion of looking time by dividing each AOI's looking time by the sum of all looking times. Lastly, we computed the mean fixation duration for each AOI by summing all fixations with durations > 120 ms and dividing by the total number of fixations.

## 2.6. Statistical analysis

As our primary interest for this study was to explore the differences between the different participant groups, metaphor and literal trials were analysed separately. For metaphor trials the number of correct responses, number of incorrectly chosen literal interpretations and incorrectly chosen control pictures were determined for each participant. For literal trials the number of correct responses was determined. No distinction between the two incorrect options was made for these trials and the number of incorrect responses is simply the number of correct responses subtracted from the number of literal trials.

Statistical analyses were performed in SPSS version 23. Analyses of

trial responses (e.g. number of metaphor trials correctly answered) were performed using generalized linear models that modelled the response as proportion of events out of a fixed number of trials (15 for metaphor trials, 7 for literal trials) and which used a logit link function between the model predictors and the dependent variable. Analyses of eye-movement data were performed using analyses of variance (ANOVAs) and *t*-tests.

## 3. Results

### 3.1. Picture selections

The proportion of responses to the different items of the PST is shown in Fig. 2. On metaphor trials, the patient group identified the correct picture significantly less often (mean proportion = 0.60, 95% Wald CI: 0.54–0.65) than healthy controls (mean = 0.80, CI: 0.74–0.84, Wald- $\chi^2$  = 22.36,  $p$  < .001). Patients (mean = 0.37, CI: 0.31–0.43) were more likely to incorrectly pick the literal picture than healthy controls (mean = 0.18, CI: 0.14–0.24, Wald- $\chi^2$  = 20.625,  $p$  < .001). Control pictures were incorrectly picked infrequently by both groups (patients: mean = 0.04, CI: 0.02–0.06; controls: mean = 0.02, CI: 0.01–0.05) and there was no significant difference in the proportion of these types of errors between groups (Wald- $\chi^2$  = 0.717,  $p$  = .397). Both groups performed equally well on the literal trials (patients: mean = 0.94, CI: 0.88–0.97; controls: mean = 0.93, CI: 0.87–0.97) with performance near ceiling level and no significant difference between them (Wald- $\chi^2$  = 0.042,  $p$  = .837).

A further generalized linear model, further looked at the type of errors participants were making in the metaphor task, by predicting the proportion of “literal” errors among all errors. Because two healthy controls did not make any errors, they could not be included in this analysis (proportion of literal errors is undefined for them). This analysis found no significant difference between groups (Wald- $\chi^2$  = 0.183,  $p$  = .669). When participants made errors on metaphor trials, the proportion of these errors that were literal was approximately the same in the patient group (mean = 0.91, CI: 0.85 to 0.95) as in the control

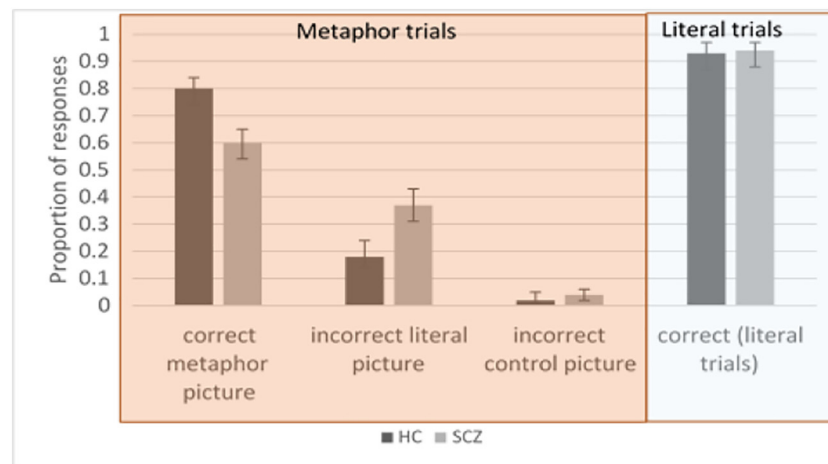


Fig. 2. Proportion of responses during the Picture Selection Task. Error bars represent 95%-Wald-Cl.

group (mean = 0.89, CI: 0.76 to 0.95). The confidence intervals for both groups were above 0.5 indicating that participants in both groups were more likely to choose the literal picture than the control picture when making an incorrect response to metaphor trials.

### 3.2. Eye-tracking

Eye-tracking data were available for 22 of the 34 participants (10 healthy controls, 12 patients). The remaining 12 participants were excluded from data analyses because they were not able to sit still enough for their eyes to be tracked or were not able to see well enough without wearing glasses; this prevented their eyes from being accurately tracked.

In the picture analysis, the three measures were submitted to separate 2 group (control, patient)  $\times$  3 AOI (control picture, literal picture, metaphor picture) mixed ANOVAs. There was a main effect of AOI for mean looking time,  $F(2,40) = 5.26$ ,  $p = .009$ , partial- $\eta^2 = 0.208$ ; mean proportion looking time,  $F(2,40) = 27.48$ ,  $p < .001$ , partial- $\eta^2 = 0.579$ ; and mean fixation duration,  $F(2,40) = 3.58$ ,  $p = .04$ , partial- $\eta^2 = 0.152$ . There was an effect at the trend level of group for mean looking time,  $F(1,20) = 3.14$ ,  $p = .09$ , partial- $\eta^2 = 0.136$  (control: mean = 1700 ms, SD = 320 ms; patients: mean = 2469 ms, SD = 292 ms). All other main effects and interactions were not significant ( $F_s < 1.80$ ,  $p_s > 0.20$ , partial- $\eta^2 < .082$ ). See Table 2.

In the literal-target analysis, we compared the three measures between control and patient participants for the literal-target AOI (the sixth of the literal picture which contained the literal depiction of the metaphor vehicle). Only the mean looking time differed between group,  $t(20) = 2.32$ ,  $p = .03$ , Cohen's  $d = 1.03$ , with patients looking at the literal target (mean = 1083 ms, SD = 215 ms) more than twice longer than control participants (mean = 501 ms, SD = 92 ms). Mean

proportion looking time ( $t = 1.302$ ,  $p = .208$ ,  $d = 0.54$ ) and mean fixation duration ( $t = 1.116$ ,  $p = .277$ ,  $d = 0.48$ ) did not differ between groups.

#### 3.2.1. Relationships between metaphor comprehension and other variables using the eye-tracking data

Across both groups (with group controlled for), the mean looking time for the literal-target AOI (Wald- $\chi^2 = 6.75$ ,  $p = .009$ ,  $r = -0.37$ ) was negatively related to the number of correctly selected metaphor pictures. For mean proportion looking time, this negative relationship existed for the literal AOI (Wald- $\chi^2 = 5.74$ ,  $p = .02$ ,  $r = -0.34$ ) and literal-target AOI (Wald- $\chi^2 = 23.27$ ,  $p < .001$ ,  $r = -0.70$ ), and was positively related to the number of correctly selected metaphor pictures for the metaphor AOI (Wald- $\chi^2 = 6.63$ ,  $p = .01$ ,  $r = 0.36$ ). All other eye-movement measures were not significantly correlated with the number of correctly selected metaphor pictures.

Table 3 shows the relationships between performance on the metaphor trials with cognitive and clinical characteristics and reveals that age and years of education predict the number of correct responses on the metaphor items of the picture selection task.

## 4. Discussion

We demonstrated reduced performance on the metaphor comprehension task in schizophrenia. This finding is broadly consistent with existing findings relating to metaphor comprehension capacities in those with a diagnosis of schizophrenia (Drury et al., 1998; Mo et al., 2008). However, the use of an action (picture selection) rather than a verbal response paradigm allows us to be more confident that the difference between the schizophrenia group and healthy control group performance is not related to the extra cognitive demands involved in

Table 2

Eye tracking data showing the time spent looking at the different picture types during the picture selection task.

	Controls (n = 10) <sup>a</sup>			Schizophrenia (n = 12) <sup>a</sup>			Comparison <sup>b</sup>		
	Metaphor picture	Literal picture	Control picture	Metaphor picture	Literal picture	Control picture	Metaphor vs Literal	Metaphor vs Control	Literal vs Control
Mean looking time (ms) <sup>c</sup>	2021 (419)	1518 (359)	1561 (270)	2741 (383)	2621 (327)	2043 (247)	n.s.	3.64 (0.002)	n.s.
Mean proportion looking time <sup>c</sup>	0.42 (0.02)	0.35 (0.02)	0.31 (0.01)	0.41 (0.01)	0.35 (0.02)	0.29 (0.01)	3.77 (0.001)	8.77 (< 0.001)	3.37 (0.003)
Fixation duration (ms) <sup>c</sup>	258 (9)	242 (12)	252 (14)	280 (9)	268 (11)	264 (13)	2.57 (0.01)	2.09 (0.05) <sup>d</sup>	n.s.

<sup>a</sup> Data shown are mean (standard error of the mean).

<sup>b</sup> Students dependent  $t$ -test. Data shown are  $t$  ( $p$ ).

<sup>c</sup> For a description of these measures, see Section 2.5 Eye-tracking Data Pre-processing.

<sup>d</sup> Indicates marginally comparisons (i.e., uncorrected).

**Table 3**

Prediction of proportion of correct responses in metaphor trials based on cognitive and clinical characteristics.

Covariate <sup>a</sup>	Effect of group in model		Effect of covariate in model	
	Coefficient (CI)	Wald- $\chi^2$	Coefficient (CI)	Wald- $\chi^2$
Age	1.025 (0.617, 1.434)	24.187, $p < .001$	−0.018 (−0.035, 0.000)	3.933, $p = .047$
Years education	0.770 (0.347, 1.193)	12.736, $p < .001$	0.078 (0.026, 0.130)	8.618, $p = .003$
FSIQ <sup>b</sup>	0.755 (0.281, 1.228)	9.759, $p = .002$	0.012 (−0.002, 0.026)	2.818, $p = .093$
NART <sup>c</sup>	0.837 (0.383, 1.292)	13.044, $p < .001$	0.009 (−0.006, 0.025)	1.449, $p = .229$
TOM <sup>d</sup>	0.858 (0.395, 1.321)	13.190, $p < .001$	0.014 (−0.025, 0.054)	0.513, $p = .474$
PANSS <sup>e</sup> total	n/a	n/a	−0.003 (−0.016, 0.010)	0.211, $p = .646$
PANSS positive	n/a	n/a	0.011 (−0.048, 0.027)	0.314, $p = .575$
PANSS negative	n/a	n/a	0.010 (−0.028, 0.047)	0.250, $p = .617$
PANSS general	n/a	n/a	−0.011 (−0.037, 0.015)	0.717, $p = .397$

<sup>a</sup> Regressions were computed across groups with group and the respective covariate as predictors. As PANSS scores were only available for patients, healthy controls were not included and the group predictor removed from the model.

<sup>b</sup> Full Scale IQ taken from the WASI.

<sup>c</sup> National Adult Reading Test (NART).

<sup>d</sup> Theory of mind measure, estimated using the Revised Eyes Test.

<sup>e</sup> Positive and Negative Symptom Scale for Schizophrenia.

verbally expressing an interpretation of the metaphor.

Across groups, when participants chose an incorrect picture during the metaphor trials, it was nearly always the literal picture that they chose, but these incorrect literal picture selections were made significantly more often by the schizophrenia group than by the healthy controls (see Fig. 2). This suggests that individuals with a diagnosis of schizophrenia are more likely than healthy individuals to interpret metaphor statements (e.g., “John is a lion”) literally, rather than figuratively, as intended.

It is commonly held that the literal meaning of the metaphor vehicle must be inhibited in order to arrive at a figurative interpretation (Gernsbacher et al., 2001; McGlone and Manfredi, 2001; Papagno et al., 2003; Pierce et al., 2010; Rubio-Fernandez, 2007). It is therefore plausible that individuals with a diagnosis of schizophrenia - a disorder associated with deficits in inhibitory control (Badcock et al., 2002; Mossaheb et al., 2014; Thoma et al., 2009) - fail to successfully inhibit features associated with the literal interpretation of the metaphor vehicle, leaving the literal meaning of the word to be accessible and salient. This interpretation of the picture selection task findings is supported by our eye-tracking data which can help provide implicit measures of inhibition. Across both groups, the proportion of time spent looking at the literal picture and the literal object within it were negatively related to the number of correctly selected metaphor pictures. This finding suggests that when an individual failed to arrive at the intended metaphorical interpretation of the metaphorical story, this was (at least in part) due to an inability to successfully inhibit the literal meaning of the metaphor vehicle. These findings tentatively suggest that individuals with a diagnosis of schizophrenia embark on the same comprehension procedure as healthy controls when interpreting novel metaphorical statements/stories, but potentially due to inhibitory control deficits, those standard comprehension procedures more often stall in these individuals, leaving them to attend more to the literal meaning of the metaphor vehicle, and ultimately arrive at a literal interpretation of the statement/story as a whole.

Inhibitory control deficits are likely to be one of multiple factors contributing to the poorer performance of our schizophrenia group on the metaphor trials of the picture selection task. While we accounted for verbal expression difficulties by including a visual response format, we were not able to account for receptive difficulties that may be present in individuals with schizophrenia. Arguably, the wider context depicted in the story assists in the selection of the correct picture more in the metaphor trials than in the literal trials, so any deficits in receptive language skills and/or in working memory could also play a role in the poorer performance of our schizophrenia group on the metaphor trials. In addition,

Years of education, Full-scale IQ, Pre-morbid IQ, and ToM scores were lower in patients compared with comparators, and age and years of education predicted performance on the metaphor items of the picture selection task. This latter finding is perhaps not surprising, given that metaphor interpretation involves the rapid integration of world knowledge (i.e., a deep understanding of the concepts used and the often complex and subtle associations between those concepts) into the interpretation process. Given that previous findings have not been consistent with respect to the relationship between ToM capacity and metaphor comprehension, and that our metaphor items were mixed with respect to the degree to which they pertained to emotional states, it is perhaps not surprising that ToM scores did not predict performance on the metaphor items. The drop in participant numbers for the eye tracking task means that we had a smaller sample size than we had hoped. To ensure a larger sample size in future studies with this population, an eye-tracking task (which can be more daunting for individuals with a diagnosis of schizophrenia) could be placed earlier on in the protocol.

The results of this pilot study confirm previous reports of impaired metaphor comprehension in schizophrenia, and for the first time, have used a novel task that was not confounded by reliance on the metalinguistic competency required to generate verbal explanation for metaphorical stories. We replicated previous findings suggesting that metaphor comprehension associates with performance on a theory of mind task and further demonstrated that increased attendance to the literal depictions of the story associates with impaired task performance. Overall our findings tentatively suggest that an inability to inhibit attention on an inappropriate literal meaning may be contributing to impaired metaphor comprehension. Further work is needed to understand the relationship between figurative language capacity and the development and maintenance of psychotic symptoms.

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### Declaration of competing interest

We have no conflicts of interest to disclose.

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## Appendix A

### Practice items (from Deamer et al., 2010; Deamer, 2013)

1. This weekend, Sally is at the park. She is having lots of fun riding on her bike in the park.
2. This weekend, Sally is at the zoo. She is having lots of fun looking at the lions.

### Metaphor items (adapted from Rubio-Fernandez, 2007)

1. John doesn't like physical contact. Even his girlfriend finds it difficult to come close to him. John is a cactus.
2. After six months without going to the barber, John was a lion.
3. Mary is very materialistic. She is only interested in men who are rich. Her latest boyfriend is a Mercedes.
4. On the dunes, someone had planted a few pine trees among the local plants. The pine trees were skyscrapers.
5. Mary loved maths but this year the teacher was very boring. Every lesson was a lullaby.
6. John spends four hours a day in the gym. His muscles are steel.
7. John likes to wear clothes that really stand out in the crowd. In his new coat, John is a banana.
8. John was making a chocolate milkshake when the lid came off the blender. When his mother saw him, she said John was a Dalmatian.
9. John loved paddling his canoe through the steep canyon. He especially enjoyed rolling over in the white water of the rapids. The river was champagne.
10. It was impossible to study at college during the maintenance work. The carpenter next door was a woodpecker.
11. Mary had been sharing a flat with John for a long time. With him she felt at ease even in silence. John was a pair of old slippers.
12. Things weren't going well for Mary. Her boyfriend had broken up with her the same week she had lost her job. Sometimes life can be a game of rugby.
13. Mary didn't like spending the night at her grandmother's. No matter how many blankets she would put on the bed, that attic room was Norway.
14. John and Mary have a new house with an amazing garden. Actually, one cannot see the end of it from the back door. Their garden is the Pacific.
15. Nobody wanted to run against John at school. John was a cheetah.

### Literal items (from Deamer et al., 2010; Deamer, 2013)

1. Sam and Mark had the weekend off, and went to a national park for the weekend. The national park was a forest.
2. Tom decided to spend the day varnishing the garden fence. The varnish Tom was using was a new brand. The varnish was highly toxic.
3. Mary went home for the holidays to the small village where she had grown up. She was surprised to see that they had developed the land next to the church. The land was a cemetery.
4. The car park outside Jane's house was in a complete mess these

days. The car park had been vandalized.

5. It had been a fierce contest. The winner of this year's competition was extremely powerful and supple. The champion is a true athlete.
6. Alice wanted to throw a party which would make a statement. She managed to organize something very special for the great hall where she was holding the party; it was an orchestra.
7. When you enter the main block, follow the signs; it is a long dark corridor.

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